

## ***INFLUENCE OF WATER TO CEMENT RATIO (W/C) ON SLUMP FLOW AND COMPRESSIVE STRENGTH OF SELF COMPACTING CONCRETE (SCC) CONTAINING PORTLAND POZZOLAN CEMENT***

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### **ABSTRAK**

*Fly ash atau abu terbang adalah limbah pembakaran batu bara yang membutuhkan area pembuangan atau penimbunan yang luas. Penimbunan abu terbang dalam jumlah yang banyak dan terus menerus akan menyebabkan terjadinya polusi yang merusak ekosistem di sekitarnya. Pencampuran abu terbang dengan semen Portland untuk membuat sejenis semen Portland Pozzolan dapat memberikan keuntungan ekologi dan membuat dan menghemat sumber daya alam. Penelitian ini menggunakan sejenis semen Portland Pozzolan yang mengandung abu terbang untuk membuat Self Compacting Concrete (SCC). Perbandingan air terhadap semen (W/C) merupakan suatu parameter yang penting dalam campuran beton. Mix desain dengan beberapa variasi (W/C) yaitu 30,35, 40% dibuat untuk mempelajari pengaruh W/C terhadap slump flow dan kuat tekan SCC.*

**Kata kunci** : *semen Portland Pozzolan, Self Compacting Concrete (SCC), perbandingan air terhadap semen (W/C), slump flow, kuat tekan.*

### **INTRODUCTION**

Fly ash is an industrial by product generated in thermal power plants which is recognized as an environmental pollutant, and therefore an alternative to discarding or depositing the fly ash in the land fills or ponds is desired. Fly ash contains pozzolanic material therefore it could be used as cement constituent to produce a type of Portland Pozzolan cement. The incorporation of fly ash in Portland cement achieves ecological benefit and material saving.

Portland Pozzolan cement containing fly ash was used to make Self Compacting Concrete (SCC) in this research. SCC is a special kind of concrete that can flow through and fill

the gaps of reinforcement and corners of forms without any need for vibration and compaction during the placing process. This concrete is applied to achieve the highest possible density of concrete in the mould that vibration can not be immersed to entire the concrete (Okamura et.al, 2003).

The water to cement (W/C) ratio is generally considered to be the governing parameter, which affects the strength and durability of concrete (Neville, 2003). Mixtures of SCC with three W/C ratios of 30, 35 and 40% were made and this research investigated the influence W/C ratio on the slump flow and compressive strength of SCC containing Portland Pozzolan cement.

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**MATERIALS AND EXPERIMENTAL**

**METHODS**

**Portland Pozzolan Cement**

The European Standard EN 197-1 (2000) identifies type II cements that may contain various materials as main constituents, in percentage ranging from 6% to 35%. Pozzolana, fly ash, ground granulated blast furnace slag (ggbs) and lime stone are the main materials that are permitted by EN 197-1. A type of Portland Pozzolan cement can be produced by intergrinding Portland cement clinker and fly ash or by dry blending of Portland cement powder and fly ash (Neville, 1995 and Antiohos et.al, 2005).

Table 1. Component oxides of Portland pozzolan cement

No.	Oxide	(%)
1	SiO <sub>2</sub> (Silica)	21.26
2	Al <sub>2</sub> O <sub>3</sub> (Alumina)	6.78
3	Fe <sub>2</sub> O <sub>3</sub> (Iron)	4.00
4	CaO (Lime)	64.56
5	MgO (Magnesia)	1.00
6	K <sub>2</sub> O (Potassa)	0.14
7	SO <sub>3</sub> (Sulfuric anhydride)	2.64

Table 2. Physical properties of Portland pozzolan cement

Properties	Portland Pozzolan Cement
<b>Specific gravity</b>	
<b>LoI (%)</b>	1.98
<b>Finesness/Blaine meter (m<sup>2</sup>/kg)</b>	360
<b>Time of setting (Vicat test) :</b>	
Initial set, minutes	100
Final set, hours	4.25
<b>Soundness (autoclave)</b>	
Expansion, % (max)	0.04
<b>Compressive strength</b>	
3 days, kg/cm <sup>2</sup>	175
7 days, kg/cm <sup>2</sup>	240
28 days, kg/cm <sup>2</sup>	320
<b>Heat of hydration</b>	
7 days, cal/g	65.00
28 days, cal/g	72.21
<b>Air content of mortar (%)</b>	5.25

Table 3. Physical properties of aggregates

Properties	Aggregates	
	Coarse (crushed stone)	Fine (river sand)
<b>Maximum size (mm)</b>	20	5
<b>Density (kg/ l)</b>	<b>Surface dry</b>	2.68
	<b>Oven dry</b>	2.63
<b>(24 hours) Water absorption (%)</b>	1.83	2.67
<b>Finesse modulus</b>	-	2.91
<b>Abrasion (%)</b>	20	-

The cement used in the current research is Indonesia manufactured Portland Pozzolan cement. This cement contains fly ash, its component oxides and the physical properties of cement are shown in Table 1 and Table 2, respectively.

**Aggregates**

The coarse aggregate used in the current research was crushed stone and fine aggregate was natural river sand. The tests for physical properties aggregates were designed in accordance with ASTM C33-03 (Standard Specification for Concrete Aggregates). Table 3 shows the physical properties of aggregates. Aggregates were used in surface dry condition.

**Mixtures Design of SCC**

Mixture design procedure was adopted from American and Japanese method of selection of mix proportion (ACI Standard Practice, ASTM and JIS). This research used a combination of a retarding admixture (retarder) and a high range water reducer (superplasticizer) to optimize the setting time and improve the fluidity of SCC. The retarder and superplasticizers meet the requirement for chemical admixtures according to ASTM- C1017/C1017M-98 (Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete) and ASTM 494/C494M-99ae1 (Standard Specification for Chemical Admixtures for Concrete).

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Table 4. Mixtures Design of SCC

W/C (%)	Volume 1 m <sup>3</sup>					
	Water (kg)	Cement (kg)	Aggregates		Superplasticizer (kg)	Retarder (kg)
			Sand (kg)	Crushed stone (kg)		
30	175.31	584.38	759.09	829.81	3.51	3.51
35	204.53	584.38	744.48	815.20	3.51	3.51
40	233.75	584.38	729.88	800.60	3.51	3.51

As it known the superplasticizers increase the workability of fresh concrete very much. However, this increase is not retained for more than 30-60 minutes. Retarder was used in an effort to retain the workability of SCC for longer time. The dosage of retarder was 0.6% by weight of cement. The superplasticizer used in this research is an aqueous solution of modified polycarboxylate. Its dosage was 0.6% by weight of cement. It should be noted that the content of retarder and superplasticizer were taken into consideration in calculation of the total and the effective water of the mixture.

**Slump Flow Test**

The freshly mixed concrete was tested for its self compactibility by using slump flow test (JIS A 1150-2001, Standard Test Method for Slump Flow of Concrete). The measurement of the slump flow indicates the free deformability of mixture. The slump flow is the average of horizontal flow (the largest diameter and the orthogonal to this) after lifting Abrams cone.

**Compaction Result and Density**

The specimen preparation was performed at room temperature of 26<sup>0</sup> C. The cylindrical specimens (15 cm in diameter and 30 cm in height) were cast in accordance with JSCE-F-515 (proposed: Standard practice for making test specimens of High Fluidity Concrete).

The shape and the density of the hardened concrete should be checked in order to evaluate the results of compaction of SCC. Cylindrical specimens were demoulded 24 h after casting and the sides, bottoms and ends of the cylindrical specimens were observed by the visualization method then the density of the hardened concrete was measured.

**Compressive Strength Test**

The specimens preparation was cured in water at 20 ± 3<sup>0</sup> C in accordance with ASTM C192/C192M-02 (Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory). Compressive strength was conducted at the age of 7 and 28 days in accordance with ASTM C39/C39M-01(Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens).

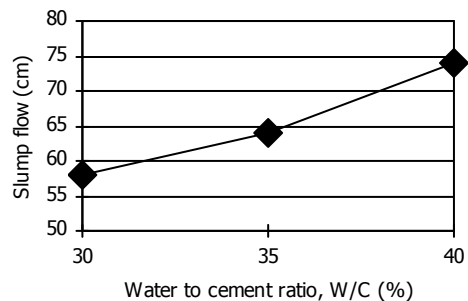


Figure 1. Slump flow versus W/C ratio

**RESULTS AND DISCUSSION**

**Slump Flow**

The results are shown in Figure 2, in terms of slump flow versus W/C ratio. The W/C ratio affected the slump flow of SCC. The more water was added, the more of deformability and flow of SCC increased.

Slump flow of SCC with W/C ratio of 30% was 58 cm. SCC with W/C ratio of 35% had slump flow of 64 cm, increased about 6 cm than SCC with W/C ratio of 30%.

SCC with W/C 40% had slump flow of 74 cm, increased about 16 cm than SCC with W/C ratio of 30 % and it was about 10 cm larger than SCC with W/C ratio of 35%.

Figure 2 shows the slump flow of SCC containing Portland Pozzolan cement. The visual observation indicated that all of the mixtures can deform and flow homogenously which the flow spread was circular. The coarse aggregates did not remain at the centre of the flow spread after removal of Abrams' cone. The result of slump flow test show that SCC containing Portland Pozzolan cement could gain the slump flow from 58 cm to 74 cm and material did not segregate.

**Compaction Result and Density**

Result of compaction and density are summarized in Table 3. The result of compaction shows that the honey comb did not occur on the cylindrical specimens, the surface of the hardened concrete was smooth and the large void did not appear. All mixtures of SCC can flow under its own weight to completely fill the mould without assistance of mechanical vibration.

The dry concrete density varied from 2328.85 to 2387.36 kg/m<sup>3</sup>. All mixtures of SCC were normal weight concrete.

**Compressive strength**

The influence of W/C ratio on the

compressive strength of SCC at 7 and 28 days are shown in Figure 3. Like another Portland cement, the strength of Portland Pozzolan cement develops with hydration time.



(a). Removal of Abrams' cone



(b). Measuring slump flow

Figure 2. Slump flow of SCC containing Portland Pozzolan cement

Table 5. Result of compaction and density

W/C (%)	Result of compaction (observed by visual method)	Density (kg/m <sup>3</sup> )
30	Good, no honey combs and large void	2387.36
35	Good, no honey combs and large void	2354.96
40	Good, no honey combs and large void	2328.85

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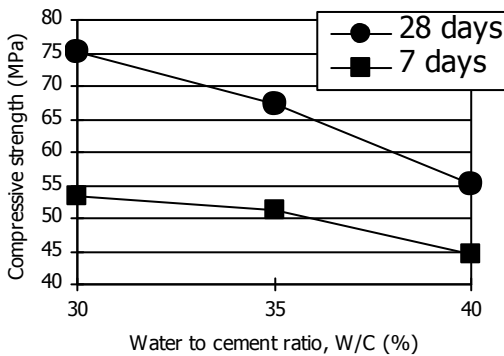


Figure 3. Result of compressive strength test

The compressive strength of SCC with W/C ratio of 30% at 7 days was 53.38 MPa and kept on increasing and reached 75.06 MPa at 28 days with a 40.61 % increase. At 7 days, compressive strength of SCC with W/C of 35 % and 40% were 51.31 MPa and 44.52 MPa, respectively.

At 28 days, compressive strength of SCC with W/C of 35 % and 40% were 67.15 MPa and 55.08 MPa, respectively.

From 7 days to 28 days, the strength development of SCC with W/C ratio of 35% and 40% were 30.87 % and 27.72%, respectively.

The water content in the mixtures also dictates the rate of the ultimate strength of the concrete. Compressive strength had an inverse relation with W/C, it can be seen that, the strength decreased as the W/C ratio increased at all the ages. This phenomenon is the same as in the conventional concrete made from Portland cement type 1, which attributed to more pores and voids formed inside the cement paste of the hardened concrete due to the higher water content. The larger volume of pores and voids lead to lower compressive strength.

## CONCLUSION

The following conclusions can be drawn from the experimental program conducted to evaluate the influence of W/C ratio on the slump flow and compressive strength of SCC containing Portland Pozzolan cement.

1. SCC containing Portland Pozzolan cement can flow homogenously and completely fill the mould.
2. Slump flow increased with the increased of W/C ratio.
3. The compressive strength was found to decrease as the W/C ratio increased.

## ACKNOWLEDGMENTS

The chemical admixtures used in the concrete mixtures cited in this paper were Sika Viscocrete-5 (superplasticizer) and Plastiment RTD-01 (plasticizer and retarder) produced by PT Sika Indonesia. Portland Pozzolan cement is produced by PT.Cement Tonasa. The tests were conducted at Material and Construction Laboratories, Department of Civil Engineering, Hasanuddin University- Makassar, Indonesia.

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